AD-A039 724 DEFENSE SYSTEMS MANAGEMENT SCHOOL FORT BELVOIR VA F/G 17/4

THE STRUCTURE OF AN A-10 ECM DECISION ANALYSIS.(U)

NOV 73 E G HUBER

UNCLASSIFIED NL

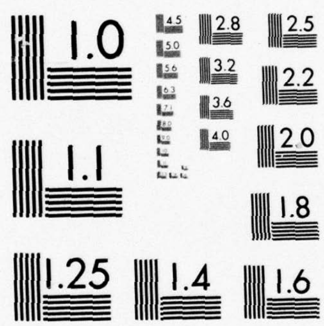
1 OF 1

AD A039724

END

DATE FILMED

6-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(2)

DEFENSE SYSTEMS MANAGEMENT SCHOOL

DEPARTMENT OF DEFENSE SYSTEMS MANAGEMENT SCHOOL

DUCTUS DOCTRINA DOMINATO

AD A 039724

Program Management Course

Student Study Program

THE STRUCTURE OF AN A-10 ECM
DECISION ANALYSIS
STUDY REPORT
PMC 73-2

Edward G. Huber
Major USAF

Fort Belvoir, Virginia 22060

HUBER

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE | READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE STRUCTURE OF AN A-10 ECM DECISION ANALYSIS		5. TYPE OF REPORT & PERIOD COVERED Student Project Report 73-2
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) EDWARD G. HUBER		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS DEFENSE SYSTEMS MANAGEMENT COLLEGE FT. BELVOIR, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS DEFENSE SYSTEMS MANAGEMENT COLLEGE FT. BELVOIR, VA 22060		12. REPORT DATE 1973-2
		13. NUMBER OF PAGES 31
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

SEE ATTACHED SHEET

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

SEE ATTACHED SHEET

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DEFENSE SYSTEMS MANAGEMENT SCHOOL

STUDY TITLE: THE STRUCTURE OF AN A-10 ECM DECISION ANALYSIS

STUDY TOPIC: To present a method on how to use a decision analysis to determine the relative attractiveness of design alternatives for the inclusion of electronic countermeasures (ECM) on the A-10 aircraft.

STUDY REPORT ABSTRACT:

With the results of the Mideast conflict showing that the Egyptians used both SA-7 and SA-6 anti-aircraft missiles to destroy many Israeli close air support aircraft, there is a new impetus to include ECM capability in the A-10 aircraft. This report is intended to show how decision analysis can be used by the A-10 Program Office to make the best possible choice between alternative methods of including ECM capabilities in the A-10. Furthermore, it is intended to show that the three most important benefits from the decision analysis technique are:

~~a.~~ 1) The systematic formulation of the problem.

~~b.~~ 2) The decomposition of the problem into its components so that individual judgements and expertise can be applied, and then the components recombined into an overall logic framework; and

~~c.~~ 3) The ability to perform sensitivity analyses on probability assumptions made in the analysis.

Student, Rank Service	Class	Date
Edward G. Huber, Major, USAF	73-2	November 1973

EDWARD G. HUBER, MAJOR, USAF

THE STRUCTURE OF AN A-10 ECM DECISION ANALYSIS

KEY WORDS: MATERIEL REQUIREMENTS ELECTRONIC COUNTERMEASURES ANTIAIR WARFARE DECISION MAKING MANAGEMENT CONCEPTS DECISION THEORY RISK ANALYSIS DELPHI TECHNIQUE

6

THE STRUCTURE OF AN A-10 ECM DECISION ANALYSIS,

9 Student Project rept.,

An Executive Summary
of a
Study Report
by

10 Edward G. Huber
Major USAF

11 Nov[redacted]973

12 34p.

Defense Systems Management School
Program Management Course
Class 73-2
Fort Belvoir, Virginia 22060

408 462 mt

EXECUTIVE SUMMARY

With the results of the Mideast conflict showing that the Egyptians used both SA-7 and SA-6 anti-aircraft missiles to destroy many Israeli close air support aircraft, there is a new impetus to include electronic countermeasures (ECM) capability in the A-10 aircraft. With that premise one can assume that there exists a decision problem in the A-10 Program Office of whether to include ECM or not to include ECM. Therefore, the object of this paper is to present a method on how to use a decision analysis to determine the relative attractiveness of design alternatives for this decision. Furthermore, it is intended to show that the three most important benefits from the decision analysis techniques are:

a. The systematic formulation of the problem.

b. The decomposition of the problem into its components so that individual judgements and expertise can be applied, and then the components recombined into an overall logic framework.

c. The ability to perform sensitivity analyses on probability assumptions made in the analysis.

The latter benefit enables the decision make to attempt to limit subjectivity and biases. It is further the purpose of this paper to show the applicability and feasibility of decision analysis to the A-10

decision problem for the layman as opposed to providing a rigorous evaluation of decision analysis. Several relevant references on the subject are provided in the annotated bibliography.

In order to illustrate a decision analysis method, a simplified decision tree was prepared which will service as an example of a method of graphically displaying decision making acts and chance events for the A-10 program. The decision tree components which include decision acts, chance events, and consequences are discussed in some detail with examples of how they apply to the A-10 decision. Inherent in the chance events is risk which is a measure of the uncertainty of the basic assumptions and estimates used. Probabilities which are assigned to these uncertainties act as a communication device to quantify the uncertainty involved in one's estimates and assumptions. The use of expert opinion is discussed as a method of quantifying the uncertainty and assigning the probability values. A method of evaluating consequences is discussed which enables one to express multiple attributes such as design to cost, loss of life and political implications into a single criterion such as dollar value. Lastly, the idea of performing a sensitivity analysis on the A-10 decision tree is discussed.

In conclusion, decision analysis is a new art that Program Managers can use to improve communications concerning complex decision

problems and to better apply the use of technical experts. It is an approach to decision making that provides a systematic, organized method for evaluating decisions under uncertainty and enables the explicit consideration of the many variables involved.

THE STRUCTURE OF AN A-10 ECM

DECISION ANALYSIS

STUDY REPORT

Presented to the Faculty

of the

Defense Systems Management School

in Partial Fulfillment of the

Program Management Course

Class 73-2

by

Edward G. Huber
Major USAF

November 1973

ACKNOWLEDGEMENTS

The author would like to express his appreciation to Major David F. Dianich, USAF for his invaluable advice and assistance in the preparation of this paper. I would further like to express my thanks to Mrs. Roger Klungle for her editing comments and typing. Also, I would like to thank my wife for her assistance and patience.

Contents

THE STRUCTURE OF AN A-10 ECM

DECISION ANALYSIS

Introduction

The large number of aircraft losses during the Vietnam War has led to a great emphasis on survivability/vulnerability of aircraft. As a result, the Air Force has made extensive efforts to design survivability into their new close air support fighter, the A-10. Some of the survivability features which have been designed into the A-10 are a completely redundant and separate flight control system, and a fully integral armored cockpit. Design criteria for survivability have been diligently derived from intelligence information, previous combat experience, and experimentation. In the mid-sixties when these criteria were defined, electronic countermeasures (ECM) capabilities were not considered necessary for the A-10. The Soviet SA-7 missile, a hand-held heat seeking anti-aircraft weapon, was

---

*ABSTAINER

This study represents the views, conclusions and recommendations of the author and does not necessarily reflect the official opinion of the Defense Systems Management School nor the Department of Defense. No formal contacts have been made with the A-10 Program Office; therefore, the discussion in this paper of any actual A-10 decision problem is purely hypothetical.

introduced into the Vietnam War in the 1970's. As a result, an ECM capability for the A-10 became a consideration. A new impetus for ECM became justified with the results of the Mideast conflict showing that the Egyptians used both SA-7 and SA-6 missiles with their armies to destroy many Israeli close air support aircraft. (1:54)[1]

With that background, one will assume that there exists a decision problem in the A-10 Program Office of whether to include ECM or not to include ECM. Therefore, the object of this paper is to present a method on how to use a decision analysis to determine the relative attractiveness of design alternatives for this decision. Furthermore, it is intended to show that the three most important benefits from the decision analysis technique are:

a. The systematic formulation of the problem.

b. The decomposition of the problem into its components so that individual judgements and expertise can be applied, and then the components recombined into an overall logic framework.

c. The ability to perform sensitivity analyses on probability assumptions made in the analysis.

---

[1] This notation will be used throughout this Study Report for sources of quotations and major references. The first number is the document or book listed in the Annotated Bibliography (pages 22-23). The second number is the page in the reference.

The latter benefit enables the decision maker to attempt to limit subjectivity and biases. It is further the purposes of this paper to show the applicability and feasibility of decision analysis to the A-10 decision problem for the layman as opposed to providing a rigorous evaluation of decision analysis. Several relevant references on the subject are provided in the annotated bibliography.

The design alternatives should include such things as pods versus integral aircraft ECM, ECM location, ECM power, design costs, etc. However, in order to show a decision analysis method, a simplified decision tree was prepared to serve as an example of the method of graphically displaying decision making acts and chance events for the A-10 program. The decision tree shown is simplified in that it illustrates the technique but does not exhaust all possible acts or events. Decision trees can be extremely complex with many branches which can only be analyzed by computer techniques, or can be deceptively simple and easily analyzed by hand computation.

To this point only decision analysis has been discussed. Inherent in any decision analysis is risk. Risk is used as the measure of the uncertainty of the basic assumptions and estimates used in the decision analysis process. Probability is then used to quantify the uncertainty (transform it into risk) of one's estimates and assumptions. It is

also used as a language to communicate, among all involved in the decision problem, the magnitude of the risk.

Due to the sensitivity and the classification of data which would be required to implement even a simple analysis of this problem, numerical results are not provided.

DECISION THEORY CONCEPTS

The following definition of decision theory will be used in this paper and applied to the A-10 decision analysis.

> Decision theory provides rational framework for choosing between alternative courses of action when the consequences resulting from this choice are imperfectly known. (2:1)

The decision making process in the face of uncertainty is an everyday occurrence in our lives. We are asked to act without knowing the full consequences of these acts. Therefore, decision theory or the method of decision analysis can be thought of as no more than a way of formalizing the logic involved in common sense. Furthermore, it allows the use of a systematic approach in making decisions on complex questions. Decision theory does not provide magical formulas for correct decisions. However, it does provide a framework wherein a decision maker can logically consider all aspects of the problem, hopefully exhausting all viable alternatives. As an integral part of decision theory, preference theory (utility theory) and the inductive use of probability theory enable the decision maker to rely on formal explicit preferences and judgements as opposed to informal unstructured intuitive reasoning.

The purpose for using decision theory is to perform a decision

analysis which consists of the following steps:

a. Charting a decision-flow diagram which is normally called a decision tree. The decision tree is made up of the significant decision acts and major chance events. The decision acts are acts that the decision maker has control over and the chance events are events which the decision maker has no control over, but which can affect the consequences of the decision problem. Depending on the nature of the uncertainty, chance events can have either discrete or continuous outcomes.

b. Determining the payoff or some measure of the outcome which is the consequence at each and every end point of the decision tree.

c. Assessing probabilities for all chance events, either discrete or continuous.

d. Analyzing the decision tree to learn more about the structure of the problem, the relative desirability of the alternatives, and the sensitivity of the problem to the driving variables.

As an example of the above process, consider the following "simple" decision in Figure 1 where a square represents an act or alternative.

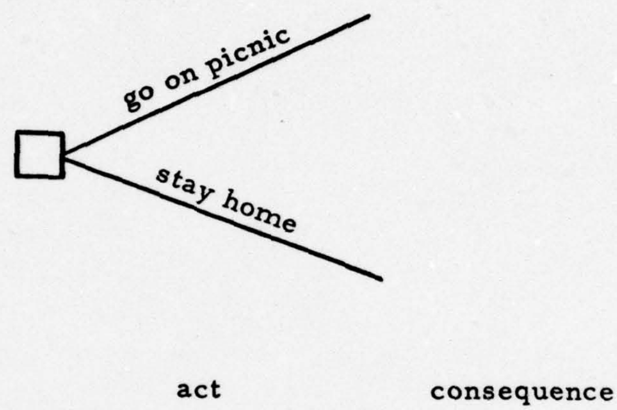


Figure 1: The First Decision Act

One can obviously think about the payoff of going on a picnic and likewise for staying home and make an appropriate decision. More obvious is that many things can happen if one goes on a picnic or stays home, each of which could make one or the other act more attractive to a decision maker. The decision analysis process advocates that to better understand the problem one should include and consider explicitly each chance event such as rain or no rain and future alternatives which could drive the problem. The first step as

noted above is to develop a decision tree which charts all the significant acts and events as shown in Figure 2.

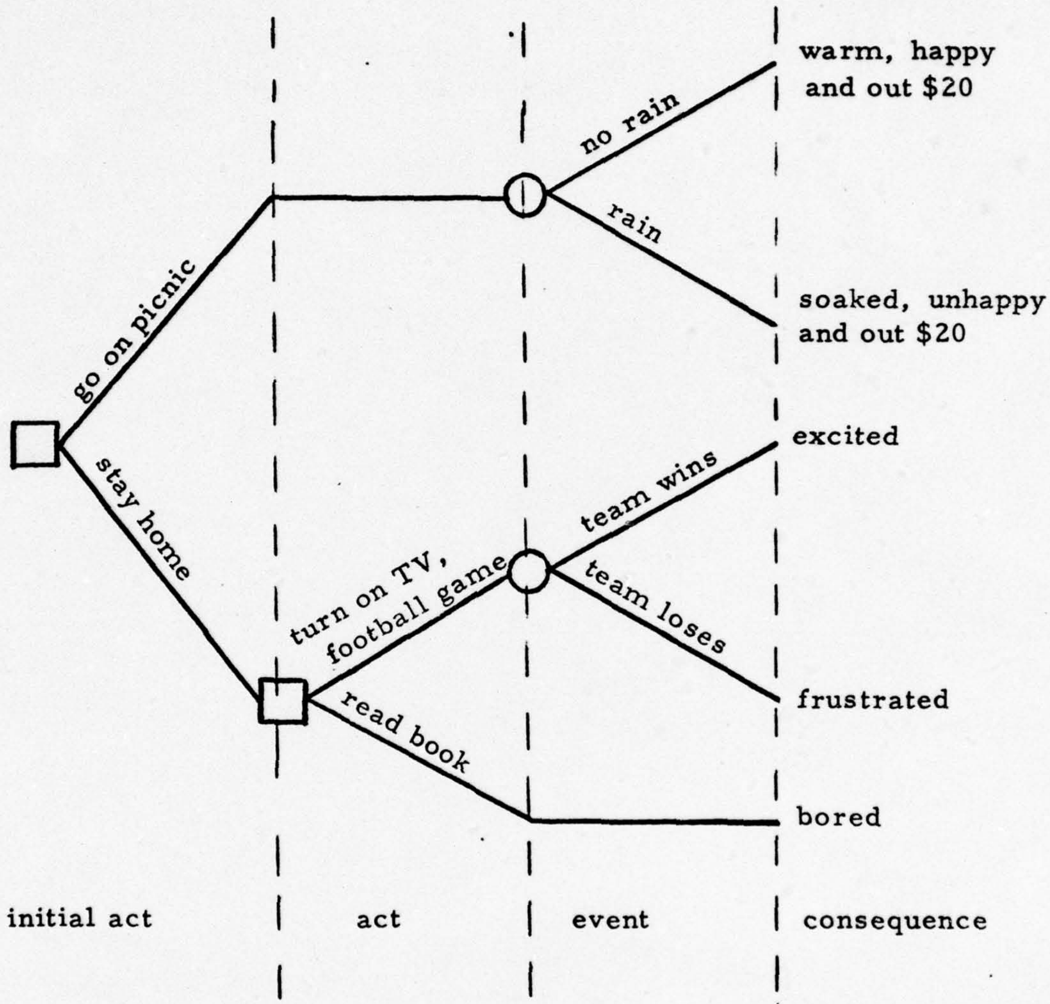


Figure 2: A Simple Decision Tree

In this next step, one could limit the analysis to intuitive thinking or one could logically look to an expert to assess the chance events (a circle represents a chance event). For example, the weather

bureau could assess the chance of rain and "Jimmy the Greek" could provide the odds for your team winning. More alternatives (acts) could be added such as playing golf and other chance events could be added which may also drive the problem such as the car breaking down. Therefore, the tree is a communicative device which can be used for decomposing the problem into components and applying judgements.

To evaluate which choice you should make at each decision act, you can use the concept of expectation (3:51). This concept says that once you have assigned probabilities to the chance events either by intuitive judgement, expert opinion, or based on historical data, one can use a process called "averaging out and folding back" to find the act which maximizes the expected payoff (4:21).

For example, if "Jimmy the Greek" says that the odds are 9 to 1 that your team will lose, then at chance event #2 there is a very high probability (.9 chance) that frustration will be the consequence. Let's assume that you would rather be bored than having a 0.9 chance of being frustrated and having only a 0.1 chance of being excited. Then at decision act #2 you would choose to read a book and so on.

In one respect, the A-10 ECM problem is structured in a manner similar to our picnic decision problem in that any decision under uncertainty problem can be structured as a sequence of acts and events.

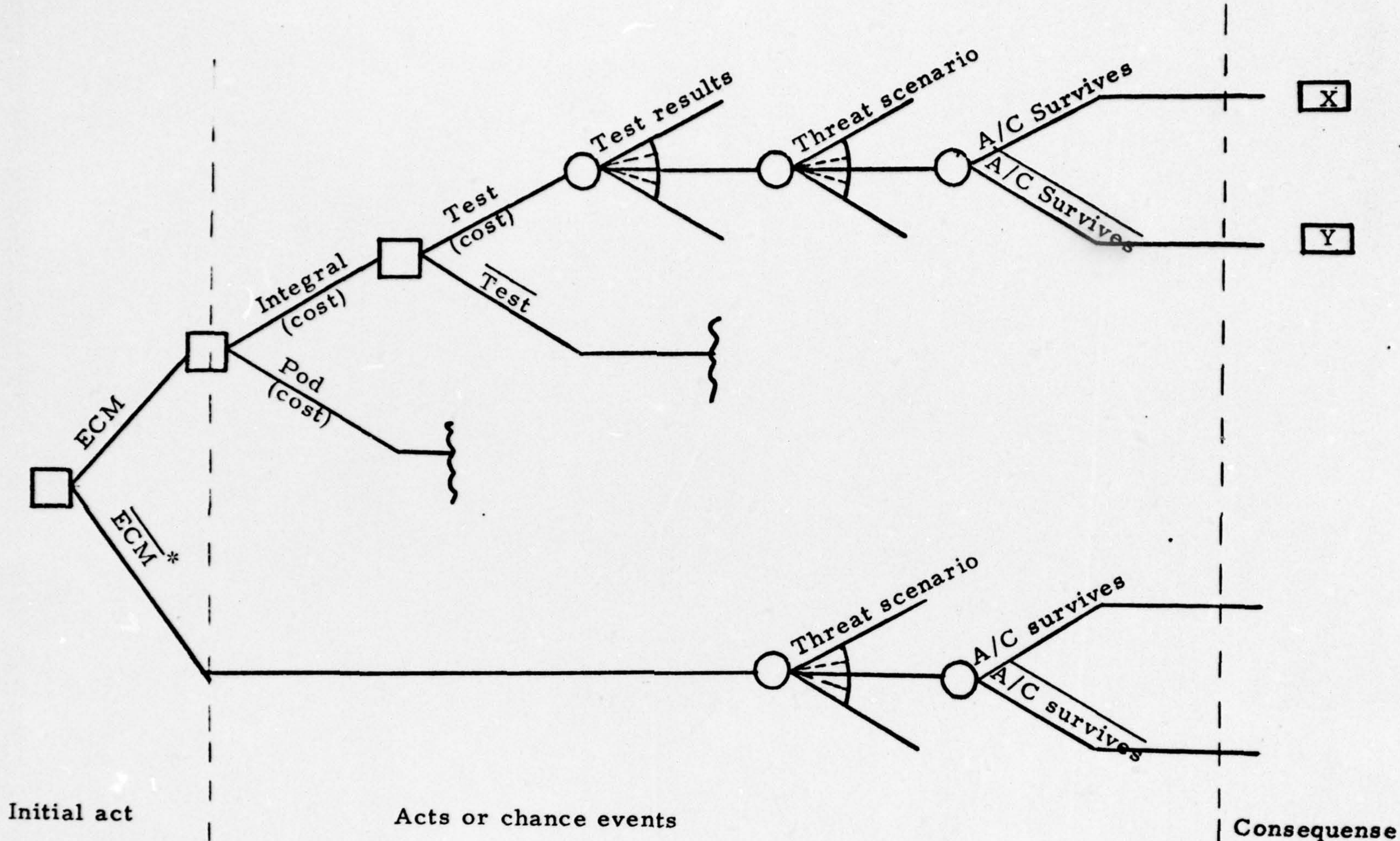
STRUCTURE OF PROBLEM

Decision Tree

The problem that will be considered in this paper is the decision of whether to provide electronic countermeasures (ECM) on the A-10 aircraft. For discussion purposes, a method for charting the decision tree for this problem is provided in Figure 3. Only one complete branch is shown since other branches could be structured in a similar manner. Obviously, the number of events or acts are not exhausted on this decision tree and a manager with more substantive knowledge of the actual A-10 program and its environment could and should mentally reconstruct the diagram to incorporate his knowledge.

Starting from left to right, the first act is a decision of whether or not to provide ECM. If one chooses ECM, the next item is the decision act of whether to provide the ECM integral to the aircraft or to provide the ECM external to the aircraft by use of a pod. From here on both branches of the tree are the same. Therefore, only the top branch "Provide Integral ECM" is shown. The next act is the decision of whether to test the ECM capability of the aircraft, again with only the top branch expanded which is discussed later.

The first chance event is the result of testing. Based on results of the tests of the aircraft, some measure of the ECM capability



*A line over an entry denotes the complement of that item; e.g., $\overline{\text{ECM}}$ means no ECM.

Figure 3 - A sample A-10 Decision Tree

would be identified. The next item would be the chance event entitled threat scenario. The evaluation of this event could be a computer simulation of the enemy threat. In this instance, a computer simulation is available and can be used to evaluate the effects on aircraft survivability of small arms, anti-aircraft artillery implacement, and SAM sites with various locations and terrain consideration. The simulation also considers the terminal effect of the threat against the aircraft or aircrafts and the aircraft attack profiles. The last chance event shown is the chance event of whether the aircraft survives or does not survive in actual but future hostilities. At the end of each branch is a terminal value or consequence which must be calculated (represented as an x in a rectangle). Also included under some of the branches is a cost required to accomplish that branch. An example is for the integral ECM branch where the cost would include such items as ECM equipment costs, testing costs, aircraft structural modification costs, and added production costs.

Since cost is a primary factor for consideration, one could evaluate this decision tree using the expected cost only which will be discussed later. Other aspects of the problem such as scheduled slips could also be assessed a monetary value. Therefore, by evaluating the decision tree for cost, the most cost effective decision could be made at each decision act of the process.

Decision Acts

The decision acts shown in Figure 3 are simple; however, they could include and illustrate many of the generic aspects of the problem and could be expanded to include more alternatives. These alternatives, as in all decision analyses, must be mutually exclusive, exhaustive, and must represent the time sequence at the latest time the decision can irrevocably be made.

As an example, consider the decision act of whether to have ECM integral to the aircraft or external in a pod where many other factors could be considered. For the integral case, the location and type of ECM should be evaluated. No feasible combination of alternatives should be eliminated initially; however, judgement must be used to limit the scope of the analysis to those alternatives deemed reasonable. This rationale should be used for all branches of the decision tree.

Another example is the test decision act where such things as the type and method of testing, the availability of an adequate test facility, and the constraints on time should be considered. All aspects of testing must be evaluated in terms of cost and feasibility. An interesting aspect of decision analysis for the decision maker is the concept of expected value of sample information (EVSI) which enables him to determine how much he should be willing to pay for testing (5:27).

By using this method, various testing schemes could be evaluated to determine the optimum course of action if cost were used as a criteria.

Chance Events

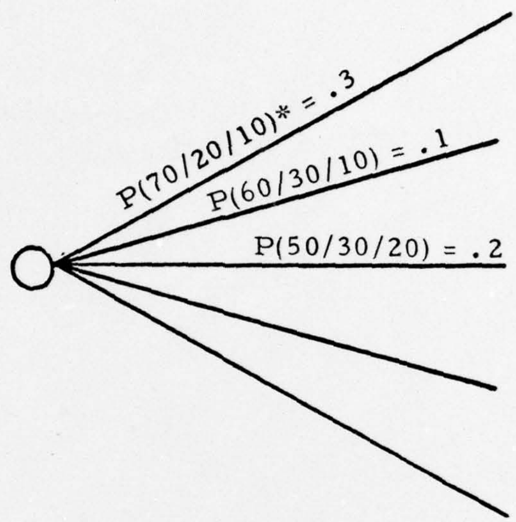
The chance events on the decision tree must be mutually exclusive, exhaustive, and must follow the rules of probability. They should also be represented in the tree at the earliest time the outcome of the chance event is known. The assignment of probabilities is based on either judgemental and subjective assessments, which require assumptions about the outcome, or on objective historical frequency data. The necessity and desirability of assigning probabilities that are "good" in some sense cannot be overemphasized. Since much of the skepticism of decision analysis is leveled at the subjective content of probabilities, the meaning of and criteria for "good" assessments should be carefully thought out prior to obtaining the assessments.

The above leads to the question of what is an expert. For this paper, an expert is defined as a person who has sophisticated knowledge in a particular subject area, such as testing. An example could be the designer of the test range or someone who has 15 years experience in testing of this nature. Another useful method of assessment is the Delphi Technique which attempts to determine a

concensus of opinion among a group of experts. As an example in the use of expert opinion, consider the A-10 test result chance event. An expert engineer with many years of experience could be used to assess what ECM frequencies could defeat the SAM simulation system or what ECM powers would be required to defeat the system. He could also assess the probabilities of the outcomes when using various combinations of the variables. If his opinion alone is not sufficient for the confidence level required by the decision maker, other equally qualified experts can be used. Then averaged or weighted probabilities could be assessed through the Delphi Technique.

Probably the most important chance event on this decision tree is the threat scenario. Here, as previously discussed, a computer simulation is used to model all aspects of the combat profile of the A-10. The scenario could include many or all combinations of the enemy threats. These combinations of enemy threats are based on intelligence estimates and actual information from the Vietnam and Mideast conflicts. An example of this chance event is shown in Figure 4. This figure shows a series of discrete events, one event being 70% small arms, 20% anti-aircraft artillery (AAA), and 10% SAM's. The probability of having that combination of threats is also shown and is the assessment which one would best get from analysts or experts in the intelligence field (6:Chapter 15). There are many things that

could be considered in additional event fans, such as types of small arms or AAA. These estimates of enemy threats and probabilities must be projected into the time frame that the A-10 will be operational, again using intelligence information.



*This is read as: P(X/Y/Z) = Probability of X% small arms and Y% anti-aircraft artillery and Z% SAM's, each of a particular type.

Figure 4: A Hypothetical Threat Scenario

The last chance event in Figure 3 is aircraft survival or non-survival which will again require the assessment of probabilities. The amount of damage to the aircraft is not considered here. However, it could be, especially if one were thinking in terms of a 30-day war which would require repairing the aircraft to fly again during the war.

Consequences

As was discussed above, the consequences a decision maker will face for each possible combination of acts and events could be evaluated using a single quantified criterion; for example, cost. When considering only cost as a consequence, it is difficult to assign monetary values as a single criterion, to such things as loss of life, design to cost considerations, and political implications. However, considerations of this nature could greatly affect the outcome of any analysis and must be addressed. An example of the problem that the analysts face is the design to cost requirements of the A-10. How does one quantify the effect of increasing the cost of the aircraft, by the addition of integral ECM, above the design to cost bogey.

A method for accomplishing an adjusted criterion approach to multi-attributed consequences is to assign a weighted index of attractiveness (6:Chapter 4). The weighted index can be any arbitrary scale for each dimension such as design to cost, say, from 0 to 100. The 0 value might be no change to the design to cost bogey, and 100 might be a $100,000 increase in the design to cost bogey. Other dimensions such as loss of life and political implications are similarly scaled and each decision option is evaluated, preferably by individuals who are affected by or must live with the consequences. Next a measure of relative importance between the dimensions is assessed

which is no more than a weighting of the dimensions. For example, design to cost should be considered 20% greater than political implications. The weighted values are then summed to give a single index which can then be applied to a criterion such as cost. This method is not always logically sound when compared to other procedures; however, it is typically much more convenient to apply.

Sensitivity Analysis

Throughout the above discussion there were instances where the elements of the problem were sensitive to various factors; particularly where one might have had low confidence in assessments of probability of outcomes. It is absolutely essential that a sensitivity analysis be performed on these elements to determine which ones should or should not be considered and to decide to what extent it should be considered. The sensitivity of the probability assessments is important in defining where the subjectivity of the analysis drives the decision and which items should be more carefully considered. An example of the use of sensitivity analysis would be in the threat scenario. Varying the probability of various mixes of SA-7's and SA-6's may show that the power of the ECM required is only dependent on the quantity of SA-6's. Therefore, subjective judgements which consider the probability of various mixes would not be important.

The amount of time that is available to make the decision, and the determination of whether it should be done within the Program Office or by the use of consultants is also a consideration. This may also dictate to what depth the analysis will be accomplished.

CONCLUSIONS

Decision analysis is a new art that Program Managers can use to improve communications concerning complex decision problems and to better apply the use of technical experts. It is an approach to decision making that provides a systematic and organized method for evaluating decisions under uncertainty while enabling the explicit consideration of the many variables involved. This is facilitated by the ability to decompose and recombine a complex decision problem. In an extreme case, it allows for the conversion of multiple criteria to a simple criterion, such as cost, so that the options can be compared using equivalent bases. It will enable the decision maker to determine the relative costs of the alternatives for which he has a choice. The ability to conduct a sensitivity evaluation of various alternatives will probably be the most valuable result of the decision analysis. A sensitive analysis enables one to learn more about his decision with an increase in the rationality of decision making. The criticism of the decision analysis method is in its subjectivity. This is not an unfair accusation; however, the use of sensitivity analysis and the use of opinions of independent technical experts will tend to eliminate preconceived biases. In fact, the systematic laying out of all alternatives should preclude the decision maker from choosing an alternative that is more costly even if it is his favorite.

A decision analysis is not a substitute for common sense or good judgement; however, it does give the program manager a more effective method of coping with risk, since it provides a logical structure for considering the decision makers judgements. The computer has been a driving force here because it shortens the time required to make sensitivity analysis and to consider many or all combinations of variables.

ANNOTATED BIBLIOGRAPHY

1. "Five Lessons of the War," Newsweek, November 5, 1973, pp. 54.
   A brief analysis of the latest Arab-Israeli War.

2. North, Warner D., "A Tutorial Introduction to Decision Theory," IEEE Transactions on Systems Science and Cybernetics, Vol. SSC-4, No. 3, pp. 200-210, September 1968.
   As the title implies, this paper provides a tutorial introduction to decision analysis using simple examples.

3. Cuff, James D., "Risk-Decision Analysis in Weapons System Acquisitions," Long Range Planning, March 1973.
   The article explains what risk-decision is, goes through a case study, and lists some of the advantages and disadvantages of risk-decision analysis.

4. Raiffa, Howard, Decision Analysis; Introduction Lectures on Choices under Uncertainty, Reading: Addison-Wesley., July 1970.
   A series of lectures which suggest a scheme one can use to organize and systematize his thinking when encountering a situation in which a difficult and complex decision must be made.

5. Peterson, C.R., Kelly, C.W., Barclay, S., Hazard, T. H., Brown, R.V., Handbook For Decision Analysis. Defense Intelligence School, August 1973.
   A case study of a hypothetical problem faced by the Commander of a small naval task force which shows how a decision analysis proceeds, using such elements as concepts of probability, subjective value, expected value, revision of probabilities, and the value of information. Also discussed is the concept of multiple dimensions of value.

6. Hurta, Donald W., Banash, Robert C., Risk Analysis in Weapons Development, DOD, Defense System Management School, May 1972.
   A discussion of risk analysis is presented along with examples to illustrate the techniques required and the tools utilized to meet various risk analysis objectives.

7. Schlaifer, Robert, Analysis of Decisions Under Uncertainty, New York: McGraw-Hill Book Co., 1969.

An introduction to logical analysis of the problems of decisions under uncertainty that arise in the practice of business administration.